

The Comprehensive Analysis of Neutrino Events Occurring inside the Detector in the Super-Kamiokande Experiment from the View Point of the Numerical Computer Experiments: Part 3

– L/E Analysis for Single Ring Muon Events II –

E. Konishi¹, Y. Minorikawa², V.I. Galkin^{3, 4}, M. Ishiwata⁴,
I. Nakamura⁴, N. Takahashi¹, M. Kato⁵ and A. Misaki⁶

¹ Graduate School of Science and Technology, Hirosaki University, Hirosaki,
036-8561, Japan

² Department of Science, School of Science and Engineering, Kinki University,
Higashi-Osaka, 577-8502, Japan

³ Department of Physics, Moscow State University, Moscow, 119992, Russia

⁴ Department of Physics, Saitama University, Saitama, 338-8570, Japan

⁵ Kyowa Interface Science Co.,Ltd., Saitama, 351-0033, Japan

⁶ Research Institute for Science and Engineering, Waseda University, Tokyo,
169-0092, Japan

E-mail: konish@si.hirosaki-u.ac.jp

Abstract. Following L_ν/E_ν analysis in the preceding paper of the Fully Contained Muon Events resulting from the quasi-elastic scattering obtained from our numerical computer experiment. In the present paper, we carry out the analyses of L_ν/E_μ , L_μ/E_ν and L_μ/E_μ among four possible combinations of L and E. As the result of it, we show that we can not find the characteristics of maximum oscillation for neutrino oscillation among two of three, L_μ/E_μ and L_μ/E_ν . Only L_ν/E_μ distribution can show something like maximum oscillation, however it cannot be detected owing to the neutral character of L_ν . It is, thus, concluded that the Super-Kamiokande Experiment could not have found the existence of the maximum oscillation for neutrino oscillation.

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1. Introduction

In a previous paper [1], we have carried out the L_ν/E_ν analysis, for *Fully Contained Muon Events* resulting from the quasi elastic scattering(QEL)[2] obtained from our numerical experiments, namely, the most clear cut analysis for the maximum oscillation and have shown the existence of the maximum oscillations under the neutrino oscillation parameters obtained by the Super-Kamiokande Collaboration. This fact denotes that our numerical computer experiment has been performed in right way. The maximum oscillations for the neutrino oscillation are derived from the survival probability of a given flavor, such as, ν_μ , and it is given by

$$P(\nu_\mu \rightarrow \nu_\mu) = 1 - \sin^2 2\theta \sin^2(1.27 \Delta m^2 L_\nu / E_\nu). \quad (1)$$

However, as both L_ν and E_ν are not physically measurable quantities which are attributed to the nature of neutrino and, consequently, the maximum oscillations can not be detected through analysis of L_ν/E_ν distribution, even if they really exist. In our numerical computer experiment, we can examine another possible combinations of L/E, such as L_ν/E_μ , L_μ/E_ν and L_μ/E_μ besides L_ν/E_ν . Therefore, we try to examine whether the existence of the maximum oscillation can be detected through the analysis of L/E besides L_ν/E_ν .

2. L_μ/E_μ , L_μ/E_ν and L_ν/E_μ Distributions in Our Numerical Experiment

2.1. L_μ/E_μ Distribution

As physical quantities which can really be observed are L_μ and E_μ instead of L_ν and E_ν , therefore we examine L_μ/E_μ distribution.

2.1.1. For null oscillation In Figures 1 and 2, we give the L_μ/E_μ distributions without oscillation for 1489.2 live days which is equal to the actual live days of the Super-Kamiokande Experiment[3] and 14892 live days, ten times as much as that of Super-Kamiokande Experiment, respectively. Similarly, Figures 1 and 2 show sinusoidal-like character as in Figures 6 and 7 for L_ν/E_ν in the preceding paper[1] which has no relation with the oscillation, however. Such the sinusoidal character represents the intersection effect due to the horizontal-like incident neutrino, partly the upward neutrinos and partly the downward neutrinos. Comparing Figure 1 with Figure 2, the characteristics of the uneven histogram in Figure 1 disappear in Figure 2 due to ten times statistics as much as that of the Figure 1.

2.1.2. For the oscillation In Figures 3 and 4, we give the L_μ/E_μ distributions with the oscillation for 1489.2 live days and 14892 live days, respectively. In Figure 3, we may observe the uneven histogram, something like dips coming from neutrino oscillation. However, in Figure 4 where the statistics is ten times as much as that of Figure 1, the

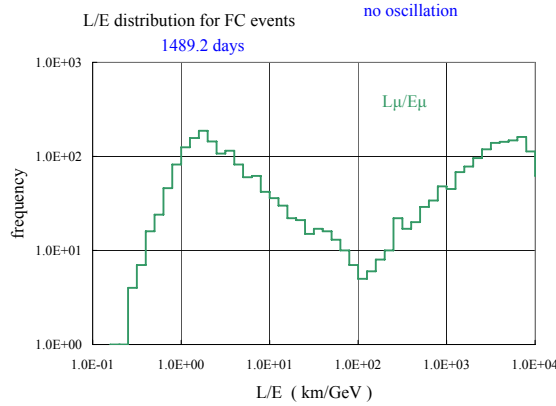


Figure 1. L_μ/E_μ distribution without oscillation for 1489.2 live days.

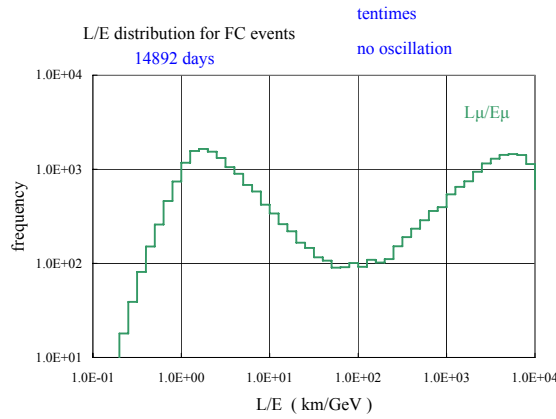


Figure 2. L_μ/E_μ distribution without oscillation for 14892 live days.

histogram becomes smoother and such the dips disappear, which turns out finally for the dips to be pseudo. Furthermore, comparing Figure 4 in the presence of neutrino oscillation with Figure 2 in the absence of neutrino oscillation, it is clear that the dips which show maximum oscillation in the Figure 10 in the preceeding paper[1] are lost in the Figure 4 under cover of the complicated relation between L_ν and L_μ . It is impossible to extract the neutrino oscillation parameters from the comparison of Figure 4 with Figure 2.

In Figures 5 and 6, correspondingly, we give the correlation between L_μ and E_μ for 1489.2 live days and 14892 live days, respectively. It is clear from the figures that we can not observe any combination of L_μ/E_μ which gives the maximum oscillation on the contrary to Figures 11 and 12 in the preceeding paper[1]. Namely, we may conclude that we can not observe the sinusoidal flavor transition probability of neutrino oscillation against the claim by the Super-Kamiokande Collaboration[4] when we adopt physically observable quantities, such as L_μ and E_μ .

In order to confirm the disappearance of the psuedo maximum oscillations, in Figures 7 and 8, we give the survival probability of a given flavor for L_μ/E_μ distribution, namely,

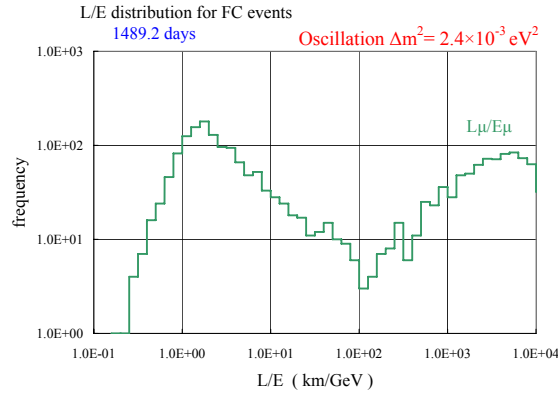


Figure 3. L_μ/E_μ distribution with the oscillation for 1489.2 live days.

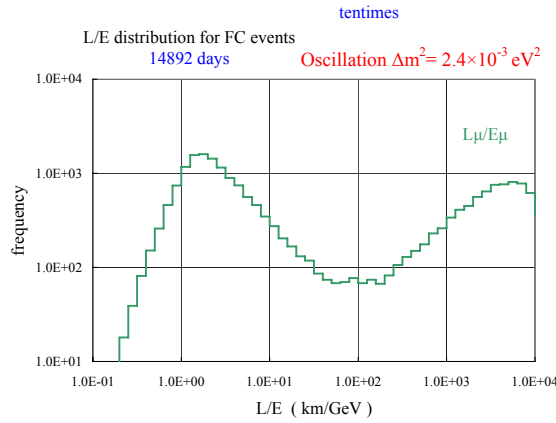


Figure 4. L_μ/E_μ distribution with the oscillation for 14892 live days.

$(L_\mu/E_\mu)_{osc}/(L_\mu/E_\mu)_{null}$, for 1489.2 live days and 14892 live days, respectively. Comparing Figure 7 with Figure 8, pseudo dips in Figure 7 disappear in Figure 8. Thus the histogram becomes a rather decreasing function of L_μ/E_μ in Figure 8. If we further make statistics higher, the survival probability for L_μ/E_μ distribution should be a monotonously decreasing function of L_μ/E_μ , without showing any characteristics of the maximum oscillation, which is contrast to Figures 8, 9 and 10 in the preceeding paper[1]. In conclusion, we should say that we can not find any maximum oscillation for the neutrino oscillation in the L_μ/E_μ distribution.

2.2. L_μ/E_ν Distribution

Now, we examine the L_μ/E_ν distribution which the Super-Kamiokande Collaboration treat in the thier paper, expecting the evidence for the oscillatory signatutire in atmospheric neutrino oscillations.

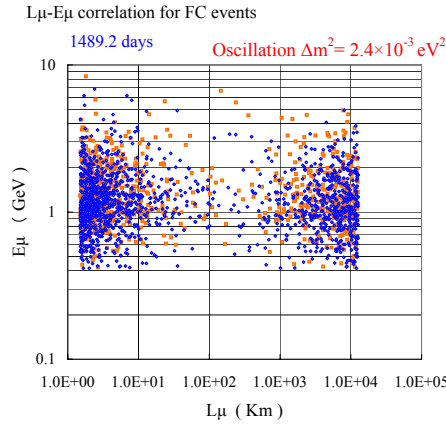


Figure 5. The correlation diagram between L_μ and E_μ with oscillation for 1489.2 live days.

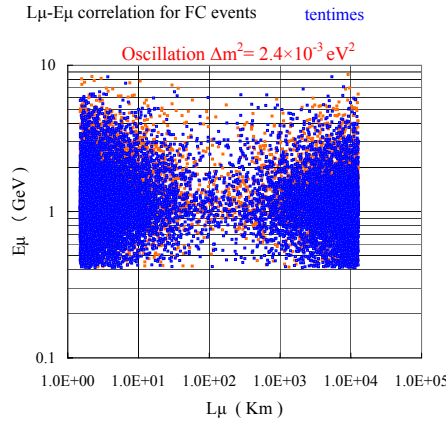


Figure 6. The correlation diagram between L_μ and E_μ with oscillation for 14892 live days.

2.2.1. For null oscillation In Figures 9 and 10, we give the L_μ/E_ν distribution without oscillation for 1489.2 live days and 14892 live days, respectively. Comparing Figure 9 with Figure 10, the larger statistics makes the distribution more smooth. Also, there is sinusoidal-like dip which have no relation with neutrino oscillation.

2.2.2. For the oscillation In Figures 11 and 12, we give the L_μ/E_ν distribution with oscillation for 1489.2 live days and 14892 live days, respectively. In Figure 11, we may find something like dip which corresponds to the first maximum oscillation near ~ 200 (km/GeV). However, such the dip disappears, by making the statistics larger as shown in Figure 12. Instead, Figure 12 gives the histogram with a little unnatural shape in spite of larger statistics. This may come from the complicated correlation between L_μ and E_ν , the details of which are shown partially in Eq.(2), Eq.(3) and Figure 5 in the preceeding paper[1].

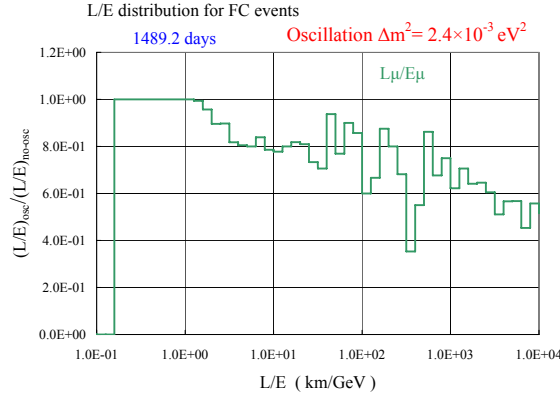


Figure 7. The ratio of $(L_\mu/E_\mu)_{osc}/(L_\mu/E_\mu)_{null}$ for 1489.2 live days.

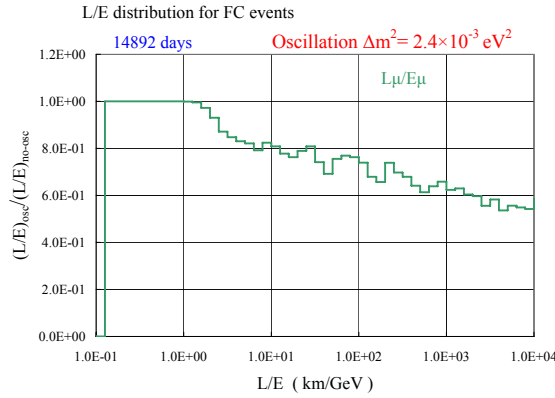


Figure 8. The ratio of $(L_\mu/E_\mu)_{osc}/(L_\mu/E_\mu)_{null}$ for 14892 live days.

2.2.3. $L_\mu/E_{\nu,SK}$ Distribution for the oscillation Instead of E_ν which is correctly sampled from the corresponding probability functions, let us utilize $E_{\nu,SK}$ which is obtained from the "approximate" formula (Eq.(4) in the preceding paper[1]). We express E_ν described in Eq.(4) in the preceding paper[1] utilized by the Super-Kamiokande Collaboration as $E_{\nu,SK}$ to discriminate our E_ν obtained in stochastic manner correctly. In Figure 13, we give $L_\mu/E_{\nu,SK}$ distribution for 14892 live days and 14892 live days, ten times as much as the Super-Kamiokande Experiment actual live days. . If we compare Figure 13 with Figure 12, we understand that there are no significant difference between them. This fact tells us that the "aproximate" formula for E_ν by the Super-Kamiokande Collaboration, which is not suitable for the treatment of the stochastic quantities, does not produce so significant error actually, which is understandable from Figure 5 in the preceding paper[1]. Also, we can conclude that we do not find any dip corresponding to any maximum oscillation from L_μ/E_ν or $L_\mu/E_{\nu,SK}$ distributions. The reason why the Figures 10 and 13 can not show any dip structure, which is shown in Figures from 8 to 10 in the preceding paper[1] clearly, comes from the situation that the role of L_ν is much more crucial than that of E_ν in the L/E analysis.

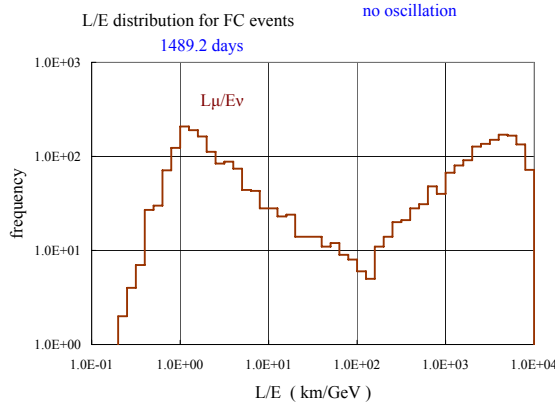


Figure 9. L_μ/E_ν distribution without oscillation for 1489.2 live days.

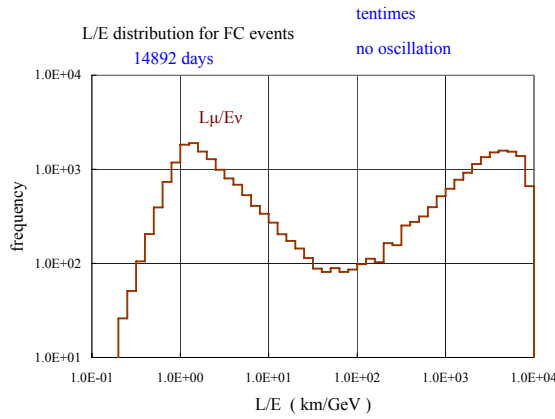


Figure 10. L_μ/E_ν distribution without oscillation for 14892 live days.

Namely, L_ν cannot be replaced by L_μ at all. Also, see the discussion in the following subsection 2.3.

2.3. L_ν/E_μ Distribution

2.3.1. For null oscillation In Figure 14, we give L_ν/E_μ distribution without oscillation for 14892 days, ten times as much as actual live days of the Super-Kamiokande Experiment to consider statistical fluctuation effect as precisely as possible. It is clear from the figure that there is not any dip corresponding to the maximum oscillation which is expected to appear in the presence of the neutrino oscillation.

2.3.2. For the oscillation In Figure 15, we give the corresponding distribution with the oscillation. In Figure 16, we give the correlation diagram between L_ν and E_μ which correspond to Figure 15. On the contrary to Figure 14, there are surely dips in Figure 15, and furthermore we can discriminate the strip pattern in Figure 16, similarly as in the Figure 12 in the preceeding paper[1].

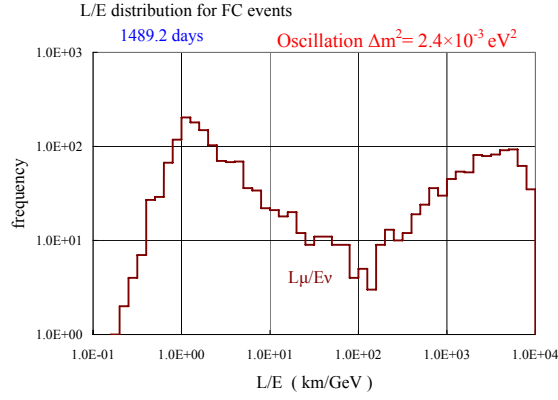


Figure 11. L_μ/E_ν distribution with the oscillation for 1489.2 live days.

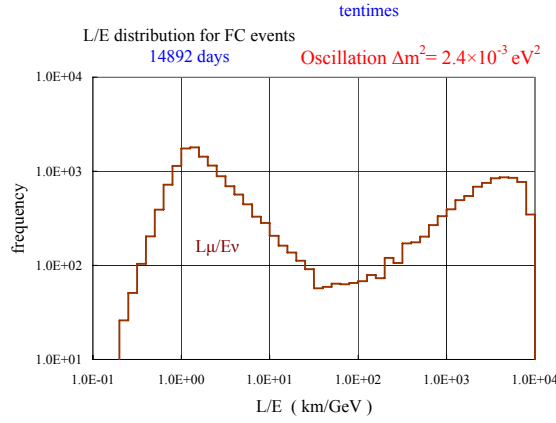


Figure 12. L_μ/E_ν distribution with the oscillation for 14892 live days.

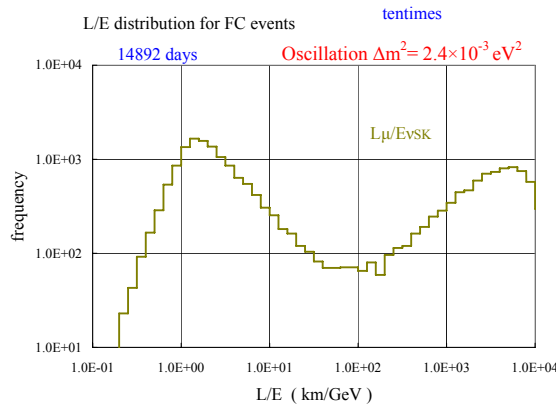


Figure 13. The $L_\mu/E_{\nu,SK}$ distribution with oscillation for 14892 day.

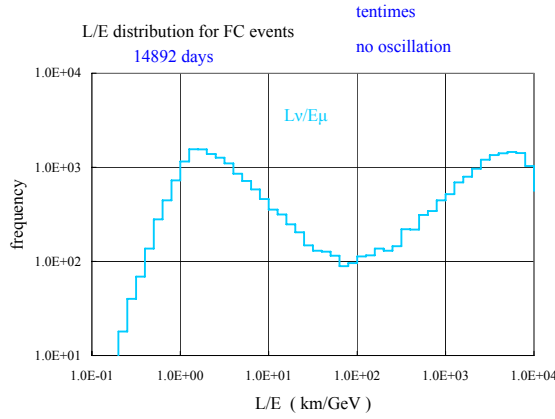


Figure 14. The L_ν/E_μ distribution without oscillation for 14892 days.

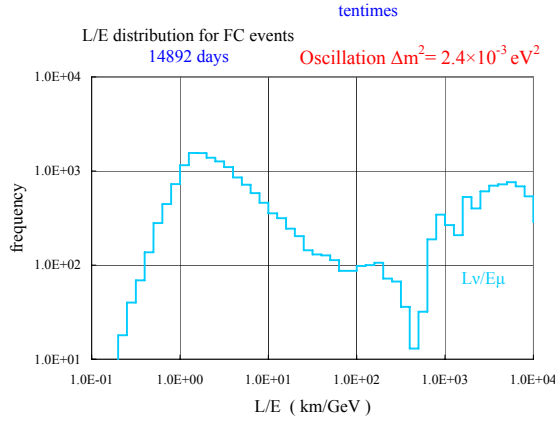


Figure 15. The L_ν/E_μ distribution with the oscillation for 14892 days.

Therefore, we suppose from Figures 15 and 16 that we may observe some quantities which is directly related to the maximum oscillations in the L_ν/E_ν distribution. However, it seems to be difficult to extract a pair of concrete values of L_ν and E_ν through the analysis of L_ν/E_μ distribution. Comparing Figure 4 with Figure 5 in the preceeding paper[1], it is clear that L_ν can not be approximated by L_μ at all, while E_ν can be approximated by E_μ within some allowance (see Figure 5 in the preceeding paper[1]). Thus, the L_ν/E_μ distribution can show some similar structure to L_ν/E_ν distribution. This fact shows that the role of L_ν is essentially important compared with E_ν in the L/E analysis. However, it should be noticed again that we can not observe the L_ν/E_μ distribution physically even if the dips surely exist in this distribution, because L_ν is the physically unobservable quantity.

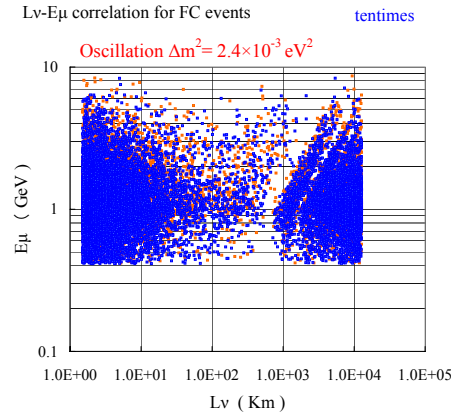


Figure 16. The correlation diagram between L_ν and E_μ with the oscillation for 14892 days.

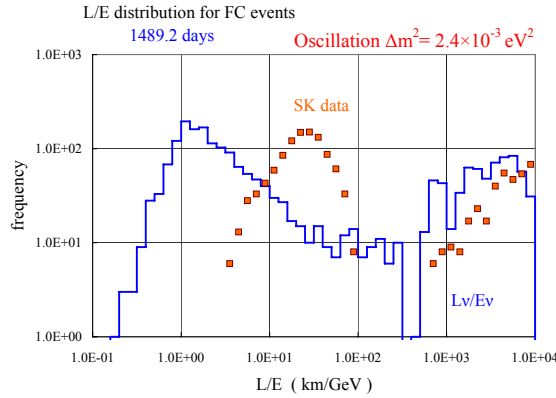


Figure 17. The comparison of L/E distribution for single-ring muon events due to QEL among *Fully Contained Events* with the corresponding one by the Super-Kamiokande Experiment.

3. Comparison of distribution from the Super-Kamiokande Experiment with our results

As the Super-Kamiokande Collaboration think that they can approximate L_μ nearly equal to L_ν and E_ν is well approximated by Eq.(4), their experimental data should be compared with our L_ν/E_ν distribution.

In Figure 17, we compare our numerical experimental data for *Fully Contained Events* due to QEL with the corresponding one by the Super-Kamiokande Experiment (read from Figure 8.22 [5]). In the light of the correct distribution, uncertainties in the distribution from the Super-Kamiokande Experiment consist of uncertainty in L_μ (see Figure 4 and Eq.(3) in the preceeding paper[1]) and in the transformation of E_ν from E_μ (see Figure 5 in the preceeding paper[1]). There are big differences between our distribution and the corresponding one from the Super-Kamiokande Experiment. The first is the difference in the shape of the distribution and the second is in their dip

structure. It seems to be curious that there exists a rather wider dip from 100 to 630 km/GeV for the first maximum oscillation in the distribution from the Super-Kamiokande Experiment, which is against the sense of maximum oscillation, while we give a sharp dip for the first maximum oscillation around 520 km/GeV predicted by the neutrino oscillation parameters from the Super-Kamiokande Collaboration. In order to clarify the reason for the remarkable difference between ours and that of the Super-Kamiokande Experiment, it is required that the Super-Kamiokande Collaboration disclose their correlation diagram between L_ν and E_ν as shown in Figure 12 in the preceeding paper[1].

4. Conclusion

The Super-Kamiokande Collaboration tries to get the evidence for an oscillatory signature in atmospheric neutrino oscillations by detecting the maximum oscillations (the first maximum oscillation). Then, they approximate L_ν by L_μ and estimate E_ν from E_μ in their L/E analysis. However, we show that the approximation of L_ν by L_μ does not hold at all (Figures 3 and 4 in the present paper) and the estimation method by the Super-Kamiokande Collaboration in energy is theoretically unsuitable (Figure 5 in the preceeding paper[1]). Then, it is clarified that the role of L_ν is more decisively crucial than that of E_ν in the L/E analysis. As a result of it, one can not replace L_ν/E_ν by L_μ/E_ν .

In the L/E analysis, we examine all possible combinations of L/E , namely, L_ν/E_ν [1], L_ν/E_μ , L_μ/E_ν and L_μ/E_μ in the present paper. Among all possible L/E analysis, we find only the L_ν/E_ν distribution can give the maximum oscillations from the survival probability of a given flavor (Eq. 1)), as it must be. However, the L_ν/E_ν distribution can not be physically observed. Even if we put aside the unsuitable estimation of E_ν from E_μ by the Super-Kamiokande Collaboration (Eq. 4 in the preceeding paper[1]), it is concluded from our analysis by the numerical computer experiment that L_μ/E_ν distribution by the Super-Kamiokande Collaboration can not obtain the maximum oscillation from the survival probability of a given flavor. From the experimental point of view, physically measurable quantities are L_μ and E_μ . Therefore, it is desirable that the Super-Kamiokande Collaboration carry out the L_μ/E_μ analysis from which they examine whether they can really observe the maximum oscillation for neutrino oscillation or not. In this case, we are free from the uncertainty which is produced by the estimation of E_ν from E_μ . However, even if the Super-Kamiokande Collaboration utilizes E_μ instead of E_ν , we can not observe the maximum oscillation in the L_μ/E_μ analysis, which are shown in Figure 8.

Furthermore, it should be emphasized that confirmation of the existence of the maximum oscillations can be carried out by the analysis on the ratio of $(L/E)_{osc}/(L/E)_{null}$, but not by that of the $(L/E)_{osc}$ only. For the purpose, we should say the numerical computer experiment is an indispensable mean. In conclusion,

we would say that we can not observe any maximum oscillations with the Super-Kamiokande Experiment L/E analysis against the original claim by the Super-Kamiokande Collaboration.

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